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WESTERN CANNONS IN CHINA IN THE 16TH–17TH CENTURIES

Yin Xiaodong*

Introduction

Gunpowder had been used in ninth century in China, and in the twelfth century explosive firearms and barrel-guns appeared,[1] the oldest gun in the world is found in China,[2] and during the next three hundred years Chinese firearms developed and kept developing. In the sixteenth and seventeenth centuries relations between China and the West intensified when Jesuit missionaries spread Catholicism in order to make Chinese people believe their religion. The missionaries took knowledge of science and technology as a stepping-stone to success, and they introduced western science and technology in China with the goal of spreading the Chistian religion. In the course of this communication process, the production and use of technology of western artillery was transferred.

Early in the 16th century, the breech-loading cannon, in China was designated as *folangji* 佛郎機 (literally translated the "Frankish culverin"), The term *folangji* 佛郎機 is the name for European, because at that time Turks, Arabs and other eastern peoples were generally referred to as Europeans. The term comes from the incorrect pronunciation for 'Frank'. This term was introduced into China probably through Moslems who lived in the east and south coastal areas of China. Later Chinese people also call western weapons *folangji* 佛郎機. It is the transliterated name.[3]

Almost at the same period, the musket, in China designated as *niaochong* 鳥銃 (literally translated the "bird gun"), or as *niaozuichong* 鳥嘴銃 (literally translated the "bird-beak gun"), was brought to China from the West. Because the musket can shoot birds in the woods, and also the gunstock looks like the beak of bird, the musket is called bird-gun too.[4] After the breech-loading cannon and musket came to China, and were copied in China, they soon played a major role in Chinese weaponry.

By the early 17th century, China's government obtained further cannons from the West, namely the muzzle-loading cannon. It is always called *xi yang huo pao* 西洋火炮 "western cannon". Chinese

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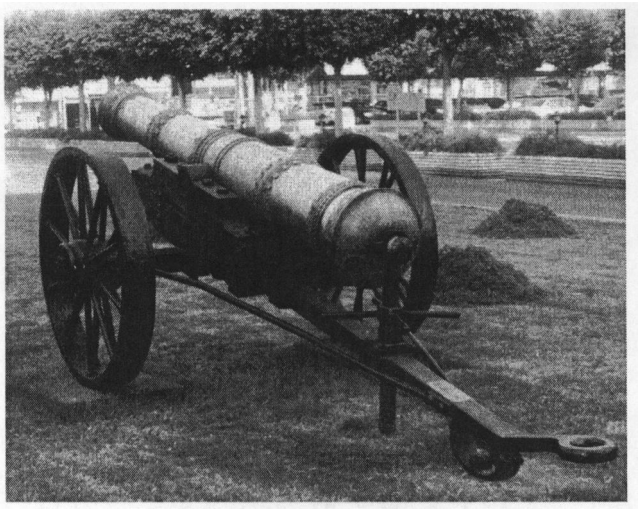

Figure 1: The cannon named "Wucheng General Firm Forever" made in 1689.

people believe that the muzzle-loading cannon is like a great general since this kind of cannon has more power, so they usually named the muzzle-loading cannon "general". For example this cannon in the picture is named *Wucheng Yonggu Dajiangjun* 武成永固大將軍 "Wucheng General Firm Forever" made in 1689, bronze cannon for the Emperor Kang-xi 康熙 (1654–1722).[5]

Then breech-loaders, muskets, and muzzle-loading cannon were introduced into China successively by capture and purchase. China improved the traditional firearms and introduced western firearms actively due to the tension from the North of China between the 16th to 18th centuries. During this time, on China's northern frontiers Manchus (later known as the Qing dynasty) grew quickly and continually attacked Ming China. So, from the sixteenth to the eighteenth centuries, these three centuries were special for Chinese firearms. Western firearms upgraded China's technology of firearm and military tactics, and became an important technology in Ming China (1368–1644).

The introduction of western firearms during the sixteenth and seventeen centuries can be divided into two stages based on the technological character and the manner of introduction of these three firearms. The first stage is from 1506 to 1620, in which the

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breech-loading cannon and the musket were introduced with capture and paying tributes, and the Ming government copied them. The second stage is from 1620 to 1690, in which the muzzle-loading cannon entered China, and the government bought and copied it actively, and, at the same time, new characters appeared, military books from the West were translated by some Chinese military experts and some Jesuits.

1. From introduction to copying: breech-loading cannon and the musket (1506–1620)

1.1 The introduction of breech-loading cannon

From about 1506 to 1521 the breech-loading cannon were introduced into China in Guangdong 廣東 province and Fujian 福建 province which are near the sea. In 1523 China produced the earliest breech-loading cannons, and the craftsmen also came from the same Guangdong and Fujian provinces.

The description for breech-loading early appeared in the literature of 1560s, *Chouhai tubian* 籌海圖編 [*The Illustrations Seaboard Strategy and Tactics*] written by Zheng Ruozeng 鄭若曾 (1503–1570) and published in 1562, it is representative of such descriptions:

> *The (breech-loading) cannon is made of iron and measures five or six feet (Chi 尺) long. It has a large belly (chamber) and long neck (barrel). At the bulge there is a long cavity, into which five smaller chambers can be inserted in rotation, and these contain the gunpowder for firing. The (breech-loading) cannon is wrapped on the outside with wooden staves and fastened with iron hoops to ensure that it does not split. Four or five of these cannons are concealed behind a ship's bulwarks on each side, and if an enemy ship comes near, one single shot finding its target will smash the hull and send the enemy to the bottom of the sea. With this arm one can sail about at will on the high seas, and no other country's ships can match it. When a cannon of this type, and its gunpowder formula, was submitted (to the throne) by an officer, its range was found to be only 100 paces. But it was admittedly an effective weapon on shipboard, and it could also be used in the defence of city walls. However, it was not much good for carting about on open battlefields.*
>
> *Later on, when Wang Chengzhai 汪誠齋 became Minister of War, he sought permission to cast more than a thousand of such*

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cannon for issue to (defence posts on) the three frontiers. One was mounted on a wooden stand, so that it could be lowered and raised, or turned to the left and to the right (for accurate aiming). This method of mounting guns was originally developed in China, and did not come in with the Franks.

Each breech-loading cannon weighs about 200 catties (Jin 斤) [1 catty = 0.6kg], *and its three chambers weigh about 30 catties each. The single lead shot which each one contains weighs about 10 ounces (Liang 两)* [1 Liang = 0.04kg].[6]

Figures 2 and 3 are illustrations of the breech-loading cannon in the book *Chouhai tubian* 籌海圖編. These figures are illustrations of the breech-loading cannon which appeared early in China. The cannon are almost the same as the western cannon of that time, in the figures. In fact, the breech-loaders in practice were not like this, it was developed and improved through experience.

1.2 The development and improvement of the breech-loading cannon

Illustrations and descriptions of breech-loading cannon are not rare in Chinese military literature since the 1530s. This reflects the

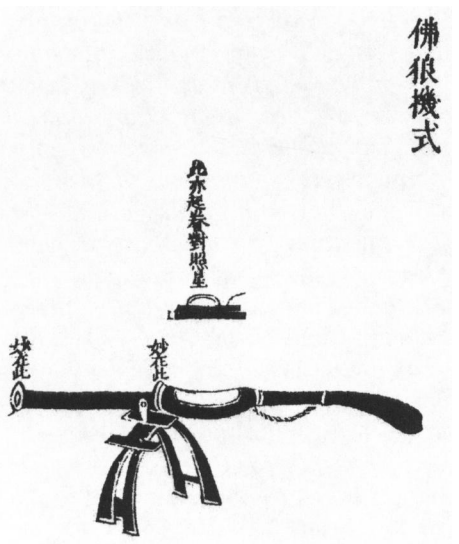

Figure 2: Breech-loading cannon.

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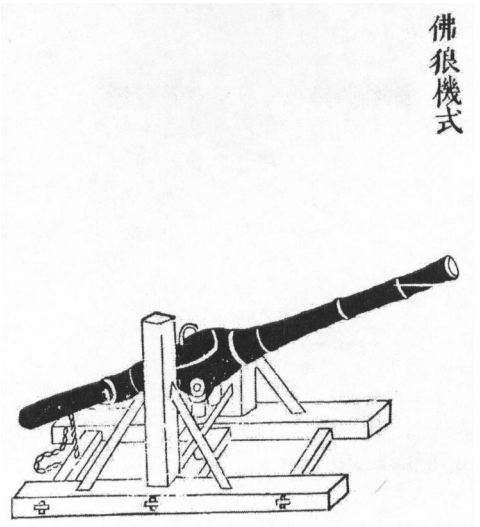

Figure 3: Breech-loading cannon[7].

breech-loading cannon's wide application. From 1523, China's government began to produce breech-loading cannon until the sixties of that century, and through practice, Chinese improved on breech-loading cannon. The most prominent master is a great general named Qijiguang 戚繼光 (1528–1588). He improved the breech-loading cannon based on the experience of actual combat since there were many such breech-loading cannon in his army. Figures 4 and 5 are illustrations drawn by Qijiguang 戚繼光. These illustrations show the actual shape and structure of Chinese breech-loading cannon.[8] Figure 6 is a small 16th century chamber. We can see that this cultural relic is the same as the illustrations drawn by Qijiguang 戚繼光.

Qijiguang 戚繼光 made the following improvements to breech-loading cannon:

Firstly, he removed the transverse peg of wood or iron, Chinese name is "Mu ma zi 木马子". It had been used in Chinese firearm hand-guns in the seventies of 14th century (figure 7).[10] According to the military literature, Chinese applied a transverse peg ("Mu ma zi 木馬子") to use breech-loading cannon when breech-loading cannon were first used in China. In the middle of figure 7, there is the transverse peg of wood or iron. It is an attachment to make

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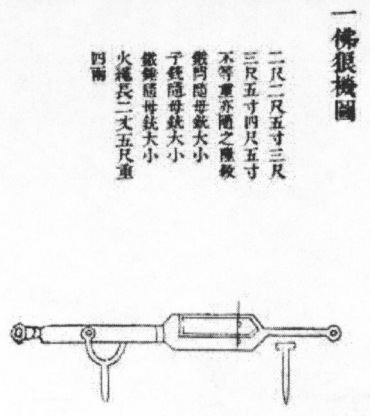

Figure 4: Breech-loading cannon.

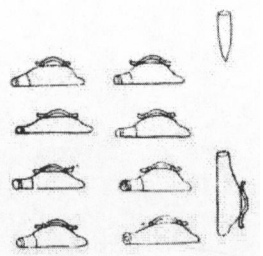

Figure 5: The chambers of breech-loading cannon[9].

the gunpowder solid after the gunpowder is loaded into the chamber, so that it enhanced the precision between the chamber and the gunpowder. It also has the occlusive function to make the balls, which were in front of it, suffer focus and immediate force of gunpowder. Therefore the gunpowder has strong erupting force, and the bullet has further range.

While Qijiguang 戚繼光 figured out that it was a misunderstanding "to use light transverse of wood to push heavy bullet" (輕馬推重子),[11] namely if the transverse of wood is installed in the

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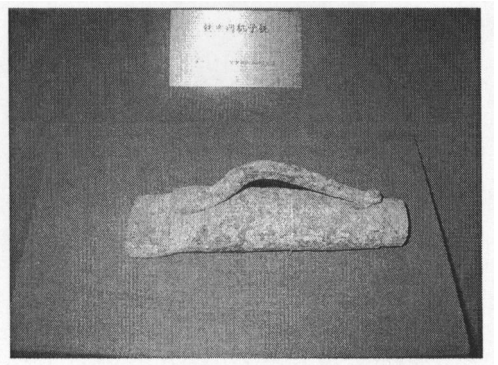

Figure 6: Chambers of breech-loading cannon in 16th century, in the Museum of Chinese Military.

breech-loading cannon, the gunpowder force firstly acts on the transverse wood after the gunpowder is lit, then the wood transverse acts on the bullet again. The wood transverse is light; while the lead bullet is heavy, so Qijiguang 戚繼光 called this "use light transverse of wood to push heavy bullet". He thought the power of bullet is weakened, so he got rid of the wood transverse. It is technical progress of loading for breech-loading cannon in China.

Secondly, a well-assorted relation between the bullet and the barrel of the cannon is required, when each bullet is loaded. Qijiguang 戚繼光 brought forward a rule about the relation

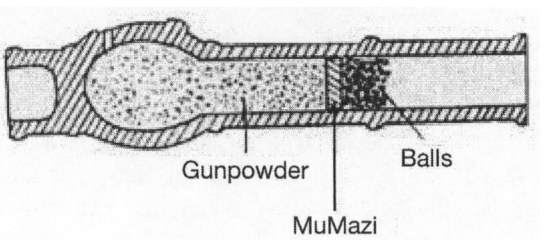

Figure 7: Diagrammatic chart of bronze hand-gun of Ming Yongle 13 明永樂十三年 (1415).

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between the diameter of the bullet and the caliber of the small chamber. That is the diameter of the bullet should be less than one "fen 分" (1/3 centimetre) than the caliber of the small chamber (今法止用鉛子，預將鉛子照子銃合口微大一分制就).[12] That means that the diameter of the bullet is bigger than the caliber of the small chamber in order to ensure the bullet and small chamber mate tightly. In figure 5, the small chamber is placed vertically facing the bullet, and the diameter is almost the same. We should pay attention to Qijiguang's 戚繼光 rule, which is similar to the western windage. In the West, the most evident character of the early firearms is the windage. It seems that the adoptive windage as a rule is always twentieth of the inside diameter of the gun tube[13], i.e. the diameter of the bullet is smaller by one-twentieth of the inside diameter of the bore. Luys Collado, a Spanish artillery expert discussed windage in detail in his book *Practica manuale dell 'arteglieria* of 1586.[14] It is interesting that the windage of China and the west is different: Qijiguang's windage is that the bullet is bigger than the inside diameter of the gun barrel, while the western windage is reverse. The western windage has two effects: one is to reduce the danger of creating a bottle-neck with the bullet, the other is to make the explosive gas dash out so as to reduce the press for the gun bore. Chinese "windage" is different from the western. This reflected that their firearm-making was not so accurate, there was always space between the bullet and the gun bore. In early China, the Chinese always used fine soil to fill up the space between the bore and bullet to prevent air leaks because the precision of the bore and bullet was not so good[15].

Thirdly, the iron crossbar is applied to prevent the small chamber recoil. In order to avoid the gun's movement, also to make the small chamber fixed in the breech when the bullet is fired, the crossbar is used at the breech end.

We can see that there is a hoop handle on the small chamber, and the tail part is one inch long, which is inserted into the breech-loading cannon so that air cannot leak, as in figure 4. In addition, the iron crossbar is inserted on the tail part to resist the recoil.

Now let us pay attention to figures 2 and 3; there was no iron crossbar in the early description of breech-loading cannon, nor any mention of the iron crossbar. This is because at the time when

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the breech-loading cannon was introduced into China, the people did not know the breech-loading cannon well, while general Qijiguang 戚繼光 possessed the practical experience of using breech-loading cannon, so there is an iron crossbar in the picture. Clearly, the breech-loading cannon like this are the actual breech-loading cannon. These improvements reflected the inaccuracy of the cannon-making at that time. At the same time breech-loading cannon were used widely. The one primary reason is the technology of casting, which has a long history in China.

1.3 The arrival and manufacture of muskets

Muskets are one of the primary firearms in the Ming and Qing Chinese army. There are several different viewpoints about their introduction. In fact, the musket was not invented in China, but was introduced into China directly and indirectly from Europe. Its first introduction happened in a battle in Guangdong 廣东 Province in 1523, in which a Ming army captured some muskets from two Portuguese warships.[16] But because Ming China did not understand the secret of musket-making, Ming China did not attach importance to the musket. In the second introduction in 1548, a Ming commander named Lutang 盧鎧 captured Japanese muskets in a battle.[17] Because the muskets made in Japan were better than the Western muskets, the Ming government ordered people to learn musket-making. Then the muskets in China were mainly learned from Japanese muskets. In fact the musket came into China through Japan from the West.

The figure 8 shows the aiming and firing of a matchlock musket,[18] figure 9 is the shape of a musket, and figure 10 is the trigger of the matchlock musket.[19]

The manufacture of muskets is more complicated than that of breech-loading cannon. The procedure of making a musket is as follows: iron making—make iron plank—coil barrel—join the barrel-bore the barrel—scalp the barrel—fix the sights, touchhole —test the barrel—fix the gunstock—fix the trigger. In this process the most difficult stage and costing most time was boring the tube. Figure 11 depicts how the workers drilled the barrel.[20] Usually the workers would spend almost one month to drill a tube, making a musket took more time than making a breech-

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Figure 8.

loading cannon. That is one main reason why the musket did not develop very well in China although it was applied widely.

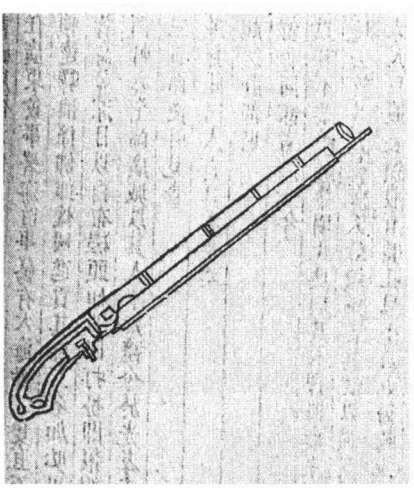

Figure 9.

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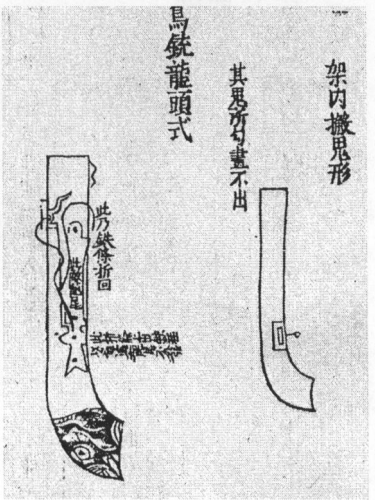

Figure 10.

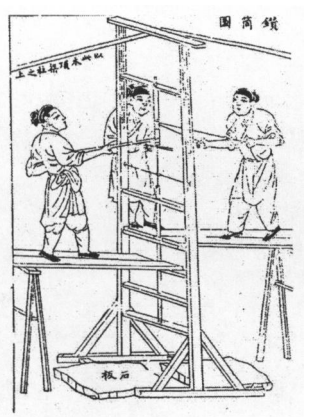

Figure 11: Boring the tube of a musket.

2 From buying cannons to translating books: muzzle-loading cannon (1620–1690)

2.1 The introduction of muzzle-loading cannon

The introduction of muzzle-loading cannon: one is directly bought from Portugal by the government twice: first in 1620,

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China bought 30 muzzle-loading cannon in Macao, at the same time invited 23 Portugal gun experts and an interpreter.[21] These 30 cannons played a key role in war, and two of them are in the Imperial Palace of Beijing now. It has been proved that these cannons were made in England,[22] there is the emblem of England on the cannon.

The second time in 1628, the officer of Guangdong 廣東 and Guangxi 廣西 Province went to Macao to buy 10 muzzle-loading cannons, and take back a Portuguese general named Goncalvo Teixeira Correa (?–1632) and experts and craftsmen. When the cannon arrived at Beijing in 1630, the emperor Chongzhen 崇禎 (1627–1644) granted the cannons the name of *Shenwei Dajiangjun* 神威大將軍 "Might General".[23]

These two events showed that, on the one hand China government made much account of muzzle-loading cannon with an active attitude, and furthermore the government needed foreign experts to teach soldiers how to apply the cannons in the process. On the other hand, the Jesuits also displayed enthusiasm to help the Chinese make cannon, and their behavior accelerated the Western gun's spread and popularity.

2.2 Jesuits introduce the cannon-making technology and knowledge of mathematics

After the Western firearms came into China, some military books about artillery-making and use, with references also to Western technology were published, were written partly by Chinese authors and partly in cooperation between Chinese and Jesuit authors. The missionaries played an important role in introducing and translating Western military books. The following three missionaries are the most important in Ming and Qing Dynasty in China:

(1) Matteo Ricci introduced the knowledge of cannon-making

In 1582, Matteo Ricci (1552–1610) came to China and introduced European science to the Chinese people. At that time some Chinese scholar-bureaucrats, who were looking for a way to make the nation strong, such as Xuguangqi 徐光啟 (1562–1633) accepted Matteo Ricci's ideas. In 1607 Matteo Ricci and Xuguangqi interpreted together Euclid's Elements, the Chinese name is *Jihe*

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Yuanben 幾何原本. In the preface to the book, the relation between geometry and firearms was mentioned for first time.[24] Matteo Ricci taught Xuguangqi cannon-making and the making of western emplacement. He was the earliest to introduced Western firearms into China.

(2) P.J. Adam Schall von Bell and Huogong Qieyao 火攻挈要

German Jesuit P.J. Adam Schall von Bell (1591–1666), who was accomplished in calendar and cannon-making, interpreted a military book *Huogong Qieyao* 火攻挈要 "*Basic Skills of Firearms Attack*" with a Chinese man named Jiao Xu 焦勖. This book included the making of field-guns, siege-guns and defence-guns. It also described the making of gun-platforms, gun-carriages, balls, gunpowder and so on. It was published in 1643. There are more than 40,000 words in three volumes, another volume of illustrations is attached; figure 12 is an illustration of siege-gun and "roaring-tiger" cannon[25] in the book. This book had wide influence on later military books.

(3) Ferdinand Verbiest made cannon for Qing government

The Belgian Jesuit Ferdinand Verbiest (1623–1688) made more than 300 muzzle-loading cannons for the emperor Kangxi 康熙.

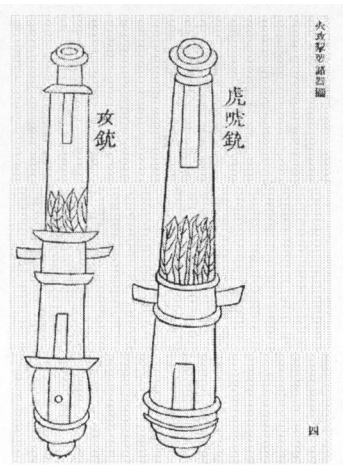

Figure 12: Siege-gun and roaring-tiger cannon.

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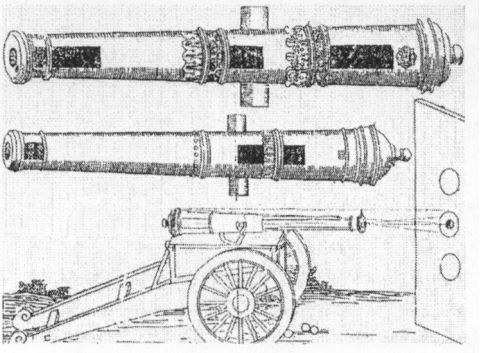

Figure 13: Test and fire.

The cannon in the figure was made under his instruction. He also tried to introduce the knowledge of science including the thinking of Aristotle (b.c.384–b.c.322).[26] Figure 13 reflects how he showed the Chinese people how to test the inside of the tube, and how to correct the trajectory in his book.[27]

Thus, Chinese accepted the Western knowledge of making cannon with the help of Jesuits. The technology was gradually standardized, based on absorbing the necessary knowledge of mathematics and geometry. In addition, Chinese also employed composite materials to make cannon. For example, some breech-loading cannon and muzzle-loading cannon were made with an iron core and bronze outside.[28] How the cannon was made is not clear, and why this material was used like this, we have not had the last word. Perhaps for cost reduction, perhaps in order to extend its useful life, but what was the function in the cannon's capability is not clear. Anyway, the craftsmen developed and innovated the cannons in material and technical reasonable selection. Therefore, Chinese absorbed the design of western firearms, and at the same time they applied Chinese traditional smelting and casting methods.

2.3 Geometry and mathematics were applied in the ballistic trajectory

With the cannon's arrival, some geometry knowledge and some technology came too. For example, the trajectory developed because of the application of the gunner's quadrant and the

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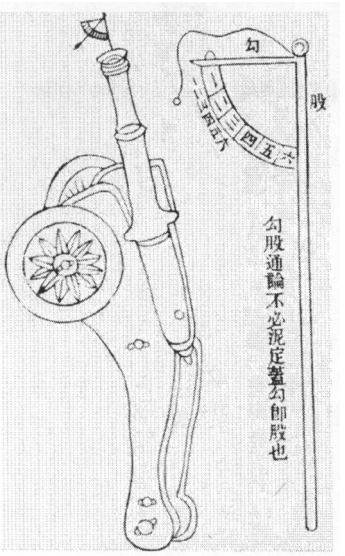

Figure 14: Gunner's quadrant.

geometrical square (Figure 14 and Figure 15).[29] Western ballistic knowledge thus entered China by virtue of Wsetern firearms.

The geometrical square was used to determine the distance from the cannon to the target and the gunner's quadrant to determine the elevation of the cannon. The principle of the geometrical square makes use of the knowledge of similar triangles. There is an illustration of a geometrical square in *Celiang fayo* 測量法義 (1607–1609) "*Method and Meaning of Survey*".[30] (Fig 15). It may be regarded as the beginning of learning measurement and calculation namely "*dushu zhixue* 度數之學", as applied in the technology of the ballistic trajectory in China.

The gunner's quadrant is to determine the elevation of the cannon so as to know the distance the ball can reach. Some literatures listed data about the range from which we can see that the range of ball increases with increase of the angle, to forty-five degrees; when the elevation is more than forty-five degrees, the range shortens instead. Manifestly the range is the maximum when the angle is forty-five degrees. Figure 16 in *Binglu* 兵錄 "*The Records of Military Art*" shows the gunner's quadrant and the plum-bob at the cannon's mouth with forty-five degrees.[31] As for

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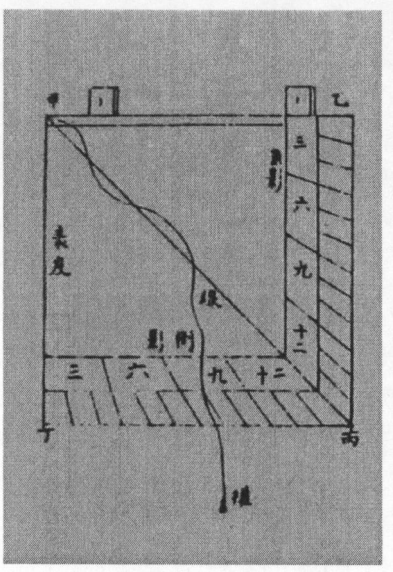

Figure 15: Geometrical square.

Figure 16: Fire with 45 degrees.

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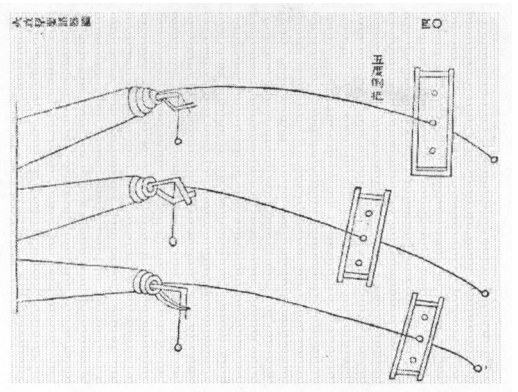

Figure 17: Test the range with angles.

these data, some are copied from Western literature,[32] and some come from the testing in practice.

This early illustration of the ballistic trajectory in China appeared in *Huogongqieyao* 火攻挈要 "*Basic Skills of Firearms Attack*" written by Schall von Bell (Figure 17).[33] According to the illustration, we can see that the curve is similar to a parabola, and is not the combination of a straight line and a curve line. An illustration about trajectory like this appeared again in *lingtai yixiang zhi* 靈臺儀象志 "*A Record of Astronomical Instruments at the Observatory*" written by Ferdinand Verbiest in 1674.[34]

Ferdinand Verbiest not only introduced the technology of making cannon, but also introduced knowledge about the ballistic trajectory. In 1683, he finished another book Qionglixue 窮理學 "*Learning to Make a Thorough Inquiry into Reason*". This book is a systematic book about Western philosophy. Ferdinand Verbiest's intention in writing this book was to expound the reasoning of the calendar and making the people know why and how to deduce much knowledge from basic theories.

In this book, Ferdinand Verbiest discussed ballistics in detail. He analyzed and explained theoretically the viewpoint of Galileo Galilei (1564–1642) about the trajectory. Firstly, he used the theory of Aristotle to explain why the track of the ball is a curve. The first section said that the movement of a body comes from two qualities, one is following the quality, the other is force quality.[35]

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Secondly, there are three tables, which give the range, height and time a ball goes in the air. They help people to deduce the range, the height and time.[36] To get these values, he first gives a base number, and calculates other values based on the base number. Ferdinand Verbiest said that one "can deduce the length or height of any shot at every possible degree of altitude, starting from the known length or height of any other shot."[37]

Conclusion

Breech-loading cannon and musket were accepted by Ming China after they were introduced in 16th century. The advantage of breech-loading cannon and musket are their design such as mother-son design, the matchlock trigger. They soon replaced the traditional firearms, including bows, and were widely used by the army. Chinese traditional technology is then used in the manufacture of breech-loading cannon and musket.

Muzzle-loading cannon were accepted by government, and Ming and Qing governments soon realized their importance in politics and military affairs, and tried to master the method of making muzzle-loading cannon. The muzzle-loading cannon is more complicated than the breech-loading cannon and musket. The design, application and making of muzzle-loading cannon need the knowledge of mathematics and geometry since the structures of the cannon, the cannonball and gunpowder have proportional relations to the caliber of the cannon. Missionaries played important roles in making and applying cannon, and they also provided much western knowledge of trajectories in practice and in theory. So the period from the 16th to 17th centuries is an important stage in the development of Chinese ballistics with the firearm's development.

Firearm-making embodied a fusion and improvement of technology in the transmission of science from the West to China in the 16th and 17th centuries since Chinese focused more on practitioners' knowledge. The manufacture of breech-loading cannon, musket and muzzle-loading cannon were not difficult for Chinese since Chinese had mastered the technology of metallurgy over a long period, and some technological innovation did appear in the 17th century.

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NOTES

* Capital Normal University, Beijing, China and Max Planck Institute for the History of Science, Berlin, Germany.

1. Joseph Needham discussed the barrel-gun in his book, "Science & Civilisation in China" vol V:7 (Cambridge University Press, Cambridge 1986), pp. 220–227.
2. The oldest cannon with an exact date is a bronze gun (also described by Wan-Kou-Chong) marked with "至顺三年" (1332) in China; now the gun is in the National Museum of China, see the "*Wen Wu* 文物 (*Cultural Relic*)", 03/1962. A newer gun marked with exact date (1298) has been found in Inner Mongolia. See the "*Wen Wu* 文物 (*Cultural Relic*)", 11/2004.
3. Dai Yixuan 戴裔煊, "*Mingshi Folangji jianzheng* 《明史·佛朗機》箋正 (*Annotation and correction for 'Mingshi. Folangji'*)". (Beijing: Zhongguo shehui kexueyuan chubanshe, 北京, 中 国科学技术出版社, Beijing, Press of Science and Technology of China, 1984) p. 1.
4. Qi Jiguang 戚繼光 (1528–1587), *Lianbing shiji zaji* 練兵實紀雜集. [*Miscellaneous Records concerning Military Training*]. Published in 1571. Zhengzhou: Henan jiaoyu chubanshe 郑州, 河南教育出版社, Zhengzhou, Henan Education Press, 1994. [Reprint]. cha5. pp. 507–508.
5. The bronze cannon is one of the cannons which was made under the direction of Ferdinand Verbiest (1623–1688) for the Emperor Kangxi in 1689. The cannon is 3 tons weight, 310 centimeter long, and the caliber is 12.5 centimeter. It is engraved with a beautiful flower pattern. In 1900, an allied army from eight countries invaded and occupied Beijing, and the commander of the allied army, Von Waldersee, carried back lots of captured equipment to Berlin from Beijing, in which several of this kind of cannon were included. Some of these cannons were melted down to supply armaments in 1930, and the cannon left were transferred to the U.K. In 1994, Chi Mei Museum (奇美博物馆) of Taiwan of China bought two cannons and set them up to be exhibited at the gate of the museum. This figure was taken by Professor Baichun Zhang in 2002.
6. Zheng Ruozeng 鄭若曾 (1503–1570), *Chouhai tubian* 籌海圖編. [*The Illustrations Seaboard Strategy and Tactics*]. Published in 1562. Zhengzhou: Henan jiaoyu chubanshe 郑州, 河南教育出版社, Zhengzhou, Henan Education Press, 1994. [Reprint] cha 13, p. 38a, b. Also see Tang Shunzhi 唐順之 (1507–1560), *Jingchuan waiji* 荊川外集. [*Other Collections of Jing Chuan*]. Published in 1573. Shanghai: Shangwu yinshuguan. 上海：商务印书馆 Shanghai, The Commercial Press 1936. [Reprint]. cha2. This English translation has corrected some words based on Joseph Needham's book. "Science & Civilisation in China" vol V:7 (Cambridge University Press, Cambridge 1986), pp. 373–376.
7. Figure 2 and figure 3 come from Zheng Ruozeng 鄭若曾 (1503–1570), *Chouhai tubian* 籌海 圖編. [*The Illustrations Seaboard Strategy and Tactics*]. Published in 1562. Zhengzhou: Henan jiaoyu chubanshe 郑州, 河南教育出版社, Zhengzhou, Henan Education Press, 1994. [Reprint]. cha 13, p. 33a.
8. Qi Jiguang 戚繼光 (1528–1587), *Lianbing shiji zaji* 練兵實紀雜集. [*Miscellaneous Records concerning Military Training*]. Published in 1571. Zhengzhou: Henanjiaoyu

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chubanshe 郑州, 河南教育出版社, Zhengzhou, Henan Education Press,1994. [Reprint]. cha5. p. 17b.

9. Figure 2 and figure 3 come from Qi Jiguang 戚繼光 (1528–1587),*Lianbing shiji* 練兵實紀雜集. [*Miscellaneous Records concerning Military Training*]. Published in 1571. Zhengzhou: Henan jiaoyu chubanshe 郑州, 河南教育出版社, Zhengzhou, Henan Education Press, 1994. [Reprint]. cha 5. p. 16b and p. 17a.
10. There was still gunpowder and bullet in the chamber when it was dug out. Furthermore, the transverse was used between the gunpowder and the bullets. Chengdong 成东, Discussion about the Bombards with Inscription in Early Ming Dynasty 明代前期有铭火铳初探, cultural relic 文物, 1988 (5); Wang Zhaochun 王兆春, History of Chinese Firearms 中国火器史, Beijing: Press of Science of military affairs 北京: 军事科学出版社, 1991, p. 101.
11. Qi Jiguang 戚繼光 (1528–1587), *Lianbing shiji zaji* 練兵實紀雜集. [*Miscellaneous Records concerning Military Training*]. Published in 1571. Zhengzhou: Henanjiaoyu chubanshe 郑州, 河南教育出版社, Zhengzhou, Henan Education Press, 1994. [Reprint]. cha5. p. 17b.
12. Qi Jiguang 戚繼光 (1528–1587), *Jixiao Xinshu* 紀效新書. [*A New Treatise on Military and Naval Efficiency*]. Published in 1562. Zhengzhou: Henan jiaoyu chubanshe 郑州, 河南教育出版社, Zhengzhou, Henan Education Press, 1994. [Reprint]. cha 15. p. 19a.
13. A.R. Hall, Ballistics in the Seventeenth Century, Cambridge at the University Press. 1952. p. 69.
14. Luys Collado, Practica manuale di arteglieria.Venice: 1586.
15. Qi Jiguang 戚繼光 (1528–1587), *Jixiao Xinshu* 紀效新書. [*A New Treatise on Military and Naval Efficiency*]. Published in 1562. Zhengzhou: Henan jiaoyu chubanshe 郑州, 河南教育出版社, Zhengzhou, Henan Education Press,1994. [Reprint]. cha.12.
16. Dai Yixuan 戴裔煊, *Mingshi Folangji jianzheng* 《明史·佛朗機》箋正. [*Annotation and correction for 'Mingshi. Folangji'*]. Published in 1984. Beijing: Zhongguoshehui kexueyuan chubanshe 北京, 中国科学技术出版社, Beijing, Press of Science and Technology of China. p. 20.
17. Zheng Ruozeng 鄭若曾 (1503–1570), *Chouhai tubian* 籌海圖編. [*The Illustrations Seaboard Strategy and Tactics*]. Published in 1562. Zhengzhou: Henan jiaoyu chubanshe 郑州, 河南教育出版社, Zhengzhou, Henan Education Press, 1994. [Reprint] cha 13, p. 29a.
18. Song Yingxing 宋應星 (1587–1666?), *Tiangong kaiwu* 天工開物. [*The Exploitation of the Works of Nature*] Published in 1637. cha 3, p. 35b.
19. Figures 9 and 10 come from Zheng Ruozeng 鄭若曾 (1503–1570), *Chouhai tubian* 籌海圖編. [*The Illustrations Seaboard Strategy and Tactics*]. Published in 1562. Zhengzhou: Henan jiaoyu chubanshe 北京, 中国科学技术出版社, Zhengzhou, Henan Education Press, 1994. [Reprint] cha 13, p. 37a, b.
20. Zhao Shizhen 趙士楨 (1553?–1611?), *Shenqi pu* 神器譜. [*Treatise on Extraordinary Weapons*]. Published in 1598. p. 11b. The method and the structure of theshaft to bore the tube of musket are very neat. Three people stand on the plank on which is put the shaft. One controls and watches the barrel to make it vertical, and the others pull the strap on the barrel face to face. The aiguille will cause the barrel pressure to move down because of the two men's weight on the plank.
21. *Ming Xizong Shilu* 明熹宗實錄. [Veritable Record of Ming Dynasty Xizong]. Cha 26. *Tianqi san nian si yue xin wei* 天啟三年四月辛未.
22. HuangYinong 黃一農, *Import of Great Ordnance from European Shipwrecks in Late-Ming China* 歐洲沉船與明末傳華的西洋大炮, Taiwan: Bulletin of the Institute of History and Philology Academia Sinica. 中央研究院歷史語言研究所集刊, 75.3, 2004, pp. 573–634.

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23. Chongzhen Changbian 崇禎長編 [Encyclopaedia of Ming Dynasty Chongzhen]. Cha 30. Chongzhen san nian zhengyue jia shen 崇禎三年正月甲申.
24. Xuguanqi and Matteo Racci only translated the first 6 chapters of *Elements*. The remaining chapters were translated by Lishanlan 李善蘭 (1811–1882). Xuguangqi realized the difference between Western mathematics and Chinese traditional mathematics, and also took cognizance of the importance of geometry to the military.
25. P.J. Adam Schall von Bell 湯若望, *Huogong Qieyao* 火攻挈要. [*Basic Skills of Firearms Attack*]. Published in 1643. Zhuqitu 諸器圖, p. 4a.
26. Ferdinand Verbiest 南懷仁 (1623–1688), *Qiongli xue* 窮理學. [*The Learning of Making a Thorough Inquiry into the Reason*]. Published in 1683. The (incomplete) book is in Beijing University.
27. The picture is stored in Jap.Sin. II67III in archives of the Societyof Jesus in Rome. See Noel Golvers. *The Astronomia Europaea of Ferdinand Verviest*, S.J. (Dillingen, 1687). Text, Translation, Notes and Commentaries. Jointly published by Institut Monumenta Serica. Sankt Augustin and Ferdinand Verbiest Foundation. Leuven, Steyler Verlag. Nettetal. 1993. Fig 26.
28. Many breech-loading cannons with iron core and bronze exterior in Ming Dynasty were found in China. Some muzzle-loading cannon with iron core and bronze exterior have been found not only in China but also in other places, for example such a cannon is in Woolwich Arsenal in the U.K. Professor Robert Smith gave me the picture of that cannon to study, I thank him.
29. Figure 14 comes from Sun Yuanhua 孫元化 (1581–1633), *Xifashenji* 西法神機. [*Western Masterpieces of Firearms*], Published in 1662. Figure 15 comes from Xu Guangqi 徐光啓 (1562–1633), *Celiang Fayi* 測量法義. [Method and Meaning of Survey] published in 1607–1609, cha "making-implement", p. 1b.
30. The book is translated by Matteo Ricci and Xu Guangqi, and the content of this book mainly comes from Christopher Clavius' (1538–1612) *Geometricae Practicae*, Romae (1604).The structure and method for applying a geometrical square was recorded in this book.
31. He Rubin 何汝賓 (?–?), *Binglu* 兵錄. [*The Records of Military Art*]. Published in 1628. cha 13, p. 3a.
32. Xiaodong Yin 尹曉冬, "A Primary Research on the Source of Western Knowledge in *Bing Lu* (*Record of Military Art*)" 火器論著《兵錄》的西方來源初探, Studies in the History of Natural Science 自然科學史研究, 2005 (2).
33. P.J. Adam Schall von Bell 湯若望, *Huogong Qieyao* 火攻挈要. [*Basic Skills of Firearms Attack*], Published in 1643. Zhuqitu 諸器圖, p. 40.
34. Ferdinand Verbiest 南懷仁 (1623-1688), 靈臺儀象志. [*A Record of Astronomical Instruments at the Observatory*]. Published in 1674. figure 117.
35. Ferdinand Verbiest南懷仁 (1623–1688), *Qiongli xue* 窮理學. [*Learning to Make a Thorough Inquiry into Reason*]. Published in 1683. An incomplete copy of this book is in Beijing University. *Xingxing thi litui bajuan* 形性之理推八卷. [*Inquire the reason for the shape and quality (of a thing) total 8 chapters*]. p. 16a, 16b.
36. idem, p. 26b–28b.
37. idem, p. 23a–24b.

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